

Highly Maneuverable Crew Transfer Vehicle Design Study

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The Highly Maneuverable Crew Transfer Vehicle (CTV) design study was undertaken to explore the effects of sharp leading edges on future reusable aerospace vehicles as part of NASA's Advanced Space Transportation Program (ASTP). More streamlined shapes should provide significant performance advantages during hypersonic flight by reducing the drag caused by the large bow shock present on blunt shapes. These performance improvements lead to significant increases in mission safety. Exploiting these advantages has been inhibited by the fact that exposing a sharp leading edge to the hostile conditions experienced during atmospheric reentry drives surface temperatures higher than can be tolerated by traditional materials. Fortunately, materials research under way at NASA Ames has led to the development of a new class of ultrahigh-temperature ceramics (UHTC) that can repeatedly survive such conditions.

Under the SHARP-CTV study project, a new CTV concept vehicle was designed that required a combination of existing tools, new analysis techniques, and new optimization processes. New methods included improving predictions of the temperature and heat flux around a sharp leading edge and the ability to calculate optimal cross-range and abort trajectories that included aerothermal performance constraints (APC). These methods were used in combination with an existing space vehicle conceptual design code called HAVOC. Aerodynamic predictions with HAVOC were benchmarked with advanced computational fluid dynamic (CFD) codes and limited wind-tunnel testing.

The SHARP-CTV-V5 design shows dramatic improvements over the blunt-nosed HL-20 in reentry cross-range and abort-safety while

meeting all other required capabilities. The team ran hundreds of low- and high-fidelity CFD analyses, optimized numerous trajectories, and constructed a low-speed wind-tunnel model to verify vehicle landing capabilities.

The improvements in performance and safety are illustrated by considering a typical due east (28-degree inclination) launch from the Kennedy Space Center (KSC). Calculations were carried out for both the HL-20 and SHARP-V5 in which it was assumed that a Titan III launch vehicle carried the CTVs to orbit. During nominal reentry or on launch abort, the CTV becomes a glider. In the case of 28-degree launch abort, the glide maneuver originates over the mid-Atlantic. Improved aerodynamics dramatically improves the capability of the vehicle to reach a greater number of alternative landing sites. In the case of HL-20, a booster failure that occurs between 64 and 390 seconds after launch results in the need to ditch into the Atlantic. For SHARP-CTV-V5 the Atlantic ditching window for a 28-degree inclination launch is from 64 to 218 seconds. The ground tracks of these abort scenarios are shown in figure 1. As shown in figure 2, similar calculations for a 51-degree (International Space Station, ISS, orbit) inclination launch from KSC produces an even more dramatic effect. HL-20 has a North Atlantic Ocean ditch window of between 355 and 403 seconds. By comparison, SHARP-CTV-V5 can always safely make an airport landing regardless of the time of booster failure.

The reduction in aerodynamic drag at hypersonic speeds not only assists in the abort safety capability but also improves the entry cross-range capability. Since ISS is at a 51-degree inclination orbit, depending on the orbital track

it is in, it may follow a ground track that takes it very far from the continental United States. If a CTV is to serve as an alternative ISS emergency escape system, it is a highly desirable capability to be able to land within the continental United States during a single orbit, irrespective of the ISS orbital track. The cross-range measures the distance away from the ground track that a vehicle is able to obtain. For HL-20 the cross-range is optimized to be 1,360 nautical miles (n.mi.), whereas for the

SHARP-CTV-V5 the optimized cross range is 3,500 n.mi. The difference between these two numbers implies that SHARP-CTV-V5 will always be able to perform the within-one-orbit escape mission, while the HL-20 would only be able to do it about half the time.

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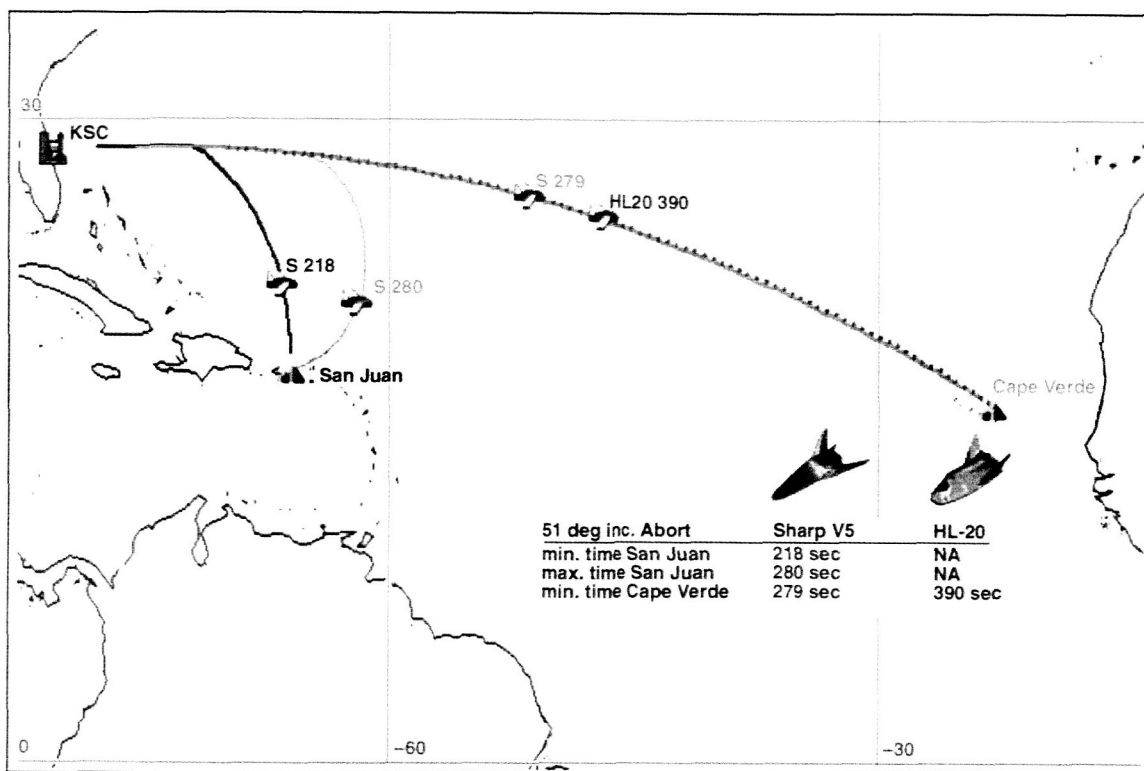


Fig. 1. Simulated ascent booster failure for both HL-20 and SHARP-V5 on a 28-degree inclination orbit.